

## CLAIMS

We claim:

- 1           1.       A method for clustering a set S of n data points to find k final centers,  
2 comprising:  
3           partitioning said set S into P disjoint pieces  $S_1, \dots, S_P$ ;  
4           for each said piece  $S_i$ , determining a set  $D_i$  of k intermediate centers;  
5           assigning each data point in each piece  $S_i$  to the nearest one of said k intermediate  
6 centers;  
7           weighting each of said k intermediate centers in each set  $D_i$  by the number of  
8 points in the corresponding piece  $S_i$  assigned to that center; and  
9           clustering said weighted intermediate centers together to find said k final centers,  
10 said clustering performed using a specific error metric and a clustering method A.
- 1           2.       A method according to claim 1 further comprising:  
2           merging said weighted centers into a single dataset  $D'$  prior to clustering.
- 1           3.       A method according to claim 1 wherein P is sufficiently large enough such  
2 that each piece  $S_i$  obeys the constraint  $|S_i| < M$ , where M is the size of a physical memory  
3 or a portion thereof to be used in processing said each piece.
- 1           4.       A method according to claim 1 wherein if P is not sufficiently large  
2 enough such that each piece  $S_i$  obeys the constraint  $|S_i| < M$ , where M is the size of a  
3 physical memory or a portion thereof to be used in processing said each piece, then  
4 iteratively performing partitioning, determining, assigning, and weighting until the sets  
5  $D'$  of weighted intermediate centers generated thereby obeys the constraint  $|D'| < M$ .
- 1           5.       A method according to claim 4 wherein said clustering is performed upon  
2 iteratively obtained weighted intermediate clusters.

1           6.       A method according to claim 4 wherein said set S is replaced by weighted  
2 intermediate centers of the previous iteration when iteratively performing said  
3 partitioning, determining, assigning, and weighting.

1           7.       A method according to claim 1 wherein said determining is performed  
2 using said specific error metric and said clustering method A.

1           8.       A method according to claim 1 wherein said specific error metric is the  
2 minimizing of the sum of the squares of the distances between points and their nearest  
3 centers.

1           9.       A method according to claim 1 wherein said specific error metric is the  
2 minimizing of the sum of the distances between points and their nearest centers.

1           10.      A method according to claim 1 wherein said clustering method is an  
2 approximation-based method.

1           11.      A method according to claim 8 wherein the distance is the Euclidean  
2 distance.

1           12.      A method according to claim 9 wherein the distance is the Euclidean  
2 distance.

1           13.      A method according to claim 1 further comprising:  
2        considering a second set of data points for obtaining a second k final centers after  
3        said set S is clustered;  
4        repeating partitioning, determining, assigning and weighting for said second set of  
5        data points; and  
6        clustering weighted intermediate centers obtained from said second set of data  
7        points together with said weighted intermediate centers obtained from said data set S, said  
8        clustering performed using said specific error metric and said clustering method A.

1           14.     A method according to claim 1 wherein said partitioning, determining,  
2     assigning and weighting is performed in parallel for each piece  $S_i$ .

1           15.     An article comprising a computer readable medium having instructions  
2     stored thereon which when executed causes clustering a set  $S$  of  $n$  data points to find  $k$   
3     final centers, said clustering implemented by:

4           partitioning said set  $S$  into  $P$  disjoint pieces  $S_1, \dots, S_P$ ;

5           for each said piece  $S_i$ , determining a set  $D_i$  of  $k$  intermediate centers;

6           assigning each data point in each piece  $S_i$  to the nearest one of said  $k$  intermediate  
7     centers;

8           weighting each of said  $k$  intermediate centers in each set  $D_i$  by the number of  
9     points in the corresponding piece  $S_i$  assigned to that center; and

10          clustering said weighted intermediate centers together to find said  $k$  final centers,  
11     said clustering performed using a specific error metric and a clustering method  $A$ .

1           16.     An article according to claim 15 further implemented by:

2           merging said weighted centers into a single dataset  $D'$  prior to clustering.

1           17.     An article according to claim 15 wherein  $P$  is sufficiently large enough  
2     such that each piece  $S_i$  obeys the constraint  $|S_i| < M$ , where  $M$  is the size of a physical  
3     memory or a portion thereof to be used in processing said each piece.

1           18.     An article according to claim 15 wherein if  $P$  is not sufficiently large  
2     enough such that each piece  $S_i$  obeys the constraint  $|S_i| < M$ , where  $M$  is the size of a  
3     physical memory or a portion thereof to be used in processing said each piece, then  
4     iteratively performing partitioning, determining, assigning, and weighting until the sets  
5      $D'$  of weighted intermediate centers generated thereby obeys the constraint  $|D'| < M$ .

1           19.     An article according to claim 1 further implemented by:

2            considering a second set of data points for obtaining a second k final centers after  
3        said set S is clustered;  
4            repeating partitioning, determining, assigning and weighting for said second set of  
5        data points; and  
6            clustering weighted intermediate centers obtained from said second set of data  
7        points together with said weighted intermediate centers obtained from said data set S, said  
8        clustering performed using said specific error metric and said clustering method A,  
9        resulting in said second k final clusters.

1            20.     A method according to claim 1 wherein said partitioning, determining,  
2        assigning and weighting is performed in parallel for each piece  $S_i$ .

1            21.     An apparatus for clustering a set S of n data points to find k final centers,  
2        said apparatus comprising:  
3            a main memory;  
4            a processor coupled to said memory, said processor configured to partition said set  
5        S into P disjoint pieces  $S_1, \dots, S_P$  such that each piece  $S_i$  fits in main memory, said each  
6        piece  $S_i$  first stored separately in said main memory and then clustered by said processor  
7        performing:  
8            for each said piece  $S_i$ , determining a set  $D_i$  of k intermediate centers;  
9            assigning each data point in each piece  $S_i$  to the nearest one of said k intermediate  
10        centers;  
11            weighting each of said k intermediate centers in each set  $D_i$  by the number of  
12        points in the corresponding piece  $S_i$  assigned to that center; and  
13            clustering said weighted intermediate centers together to find said k final centers,  
14        said clustering performed using a specific error metric and a clustering method A.

1            22.     An apparatus for clustering a set S of n data points to find k final centers,  
2        said apparatus comprising:  
3            a main memory;

4           a plurality of processors coupled to said main memory, one of said processors  
5   configured to partition said set S into P disjoint pieces  $S_1, \dots, S_P$  such that each piece  $S_i$  fits  
6   in main memory, said each piece  $S_i$  first stored separately in said main memory and then  
7   clustered by each said processor performing:  
8           for each said piece  $S_i$ , determining a set  $D_i$  of k intermediate centers;  
9           assigning each data point in each piece  $S_i$  to the nearest one of said k intermediate  
10   centers; and  
11           weighting each of said k intermediate centers in each set  $D_i$  by the number of  
12   points in the corresponding piece  $S_i$  assigned to that center, further wherein after aid  
13   weighting, one of said processors finally clustering said weighted intermediate centers  
14   together to find said k final centers, said clustering performed using a specific error  
15   metric and a clustering method A.